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(71) Applicant *(for all designated States except US)*: NEXT CENTURY TECHNOLOGIES LTD. [BS/BS]; Euro Canadian Centre, 1st floor, Marlborough Street, Nassau (BS).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: BARNES, Jim, D. [US/US]; 1301 Francis Street, Carrollton, TX 75006 (US). MEADOR, Derald [US/US]; 6901 West Mccormick Road, Amarillo, TX 78118 (US). BROCK, Don, A. [US/US]; 5629 Madge Street, Haltam City, TX 76117 (US). JANUS, Pat [US/US]; 16351 Lauder Lane, Dallas, TX 75248 (US). SEEBACH, Christopher, F., N. [US/GB]; 405 Kingston Road, London SW20 8JS (GB). ICE, Charles, L. [US/US]; 2923 Canyon Drive, Grapevine, TX 76051 (US). YOUDS, Mark [GB/GB]; 158 Monkleigh Road, Morden, Surrey SM4 4ES (GB). JARRETT, Colin [GB/GB]; Appletree House, Main Street, East Haddon, Northants NM6 8BU (GB).

(74) Agent: WHALLEY, Kevin; Marks & Clerk, 57–60 Lincoln's Inn Fields, London WC2A 3LS (GB).

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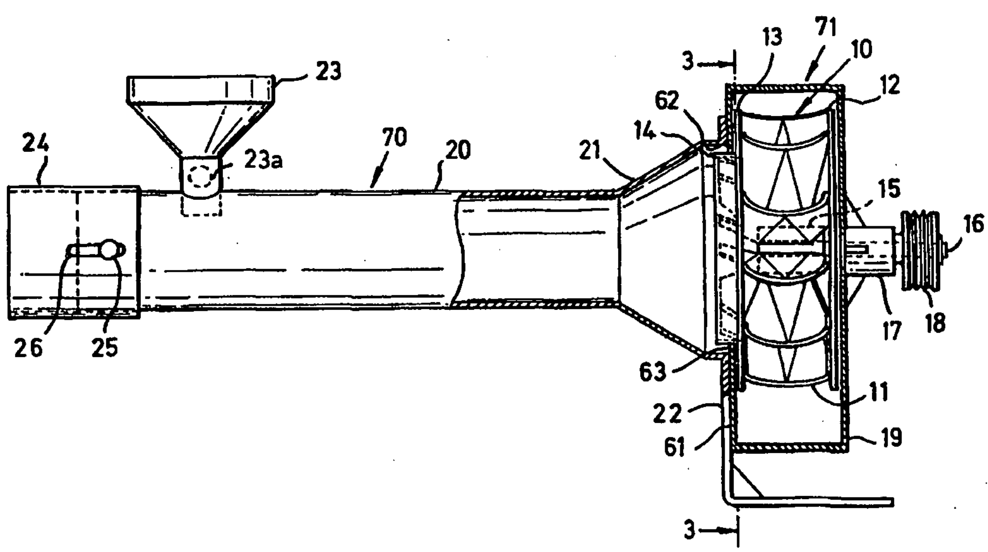

(57) Abstract

Apparatus for processing a material comprising a cyclone chamber (70); an impeller suction fan (71) for creating a cyclonic air stream within the cyclone chamber (70), the fan (71) having an inlet (14) and an outlet for passage of the air stream therethrough; an a feed assembly (23) for feeding material into the path of the cyclonic air stream for processing the material in the cyclone chamber (70), wherein the cyclonic air stream includes non–conflicting effects of vacuum forming centripetal vortices, parts of which travel at supersonic speeds; series of harmonics and subsequent subharmonics inherent in the apparatus and induced; supersonic resonance; standing wave; thermal shock; pressure changes; cavitation; the stresses of which in combination convert the potential energy of material conveyed by the cyclonic air stream to kinetic energy and a fan therefor.

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APPARATUS FOR PROCESSING A MATERIAL AND FAN THEREFOR

The present invention relates to apparatus for processing a material and an impeller suction fan for processing materials. In particular, but not exclusively, it relates to apparatus and an impeller suction fan for granulating, drying or dewatering a material.

Apparatus for granulating materials whereby no grinding element is involved are well known. The principle of such apparatus is to granulate the material due to collision and self abrasion between the individual lumps or aggregates of the material within at least one vortex formed in a cyclonic air stream.

US Patent No. 5402947 describes such an apparatus in which an air stream at high pressure, together with the material to be granulated, is fed into a cyclone chamber. A single vortex formed within the chamber entraps the material and subjects it to violent turbulence thereby causing it to break up through collision and self-abrasion. However, the movement of the material within the vortex causes severe abrasion and wear of the walls of the cyclone chamber.

It has been found that the pressure of the air stream within the conduit is an important factor in the processing process, sub-atmospheric pressure being obligatory and the actual working pressure critical to efficient operation. Therefore, the air must be drawn through the conduit by a suction fan or blower through which the air stream and entrained particulate material must eventually pass. The fan would, therefore, be subject to severe wear from the passage therethrough of the particles entrained within the air stream which are travelling at very high velocities. Such pneumatic or vacuum comminution is described by US Patent No. 3 147 911. This particular comminution was utilised for crop grinding. It comprised a vertically rotating fan in a housing having a horizontal inlet along the fan axis. However, the fan was subject to severe wear with unacceptable metal losses from the blades of the fan. Furthermore, the apparatus was not suitable for processing harder material such as stone, coal, cement etc.

The present invention seeks to overcome the above mentioned disadvantages by providing apparatus capable of processing very hard materials efficiently whilst minimising wear of the fan.

It has been found that a cyclone created in a stream of air passing through a conduit, preferably of circular cross-section, the centripetal forces created by the motion of the air stream pull any particulate material entrained in the air stream away from the walls of the conduit and towards its central region. If a wide range of sonic frequencies are created within the conduit, a pattern of powerful vortices are created in the air stream. Energies are released by conversion of the potential energy to kinetic energy due to the stresses created within the cyclone which causes a minute explosion. The vortices of the cyclone take the form of implosions which are capable of breaking the material up further into smaller particles.

It has also been found that the vortices created in the cyclonic air stream carry further harmonic frequencies generated by the specially designed apparatus, this sets up a pulse from the standing wave configuration within the system, and this causes pockets of air within the standing wave to achieve a velocity beyond the sonic range. This can be tuned for a particular type of material which enhances the ability of the vortices created to break up very hard and soft materials such as stone and to dry materials.

This phenomenon can be achieved by apparatus for processing a material, according to a first aspect of the present invention comprising a cyclone chamber; an impeller suction fan for creating a cyclonic air stream within the cyclone chamber, the fan having an inlet and an outlet for passage of the air stream therethrough; and a feed assembly for feeding material into the path of the cyclonic air stream for processing the material in the cyclone chamber, wherein the cyclonic air stream includes non-conflicting effects of vacuum forming centripetal vortices, parts of which travel at supersonic speeds; series of harmonics and subsequent subharmonics inherent in the apparatus and induced; supersonic resonance; standing wave; thermal shock; pressure changes; cavitation; the stresses of which in combination convert the potential energy of material conveyed by the cyclonic air stream to kinetic energy.

Preferably, the cross-sectional area of the cyclone chamber is within the range of 24 to 29% of the cross-sectional area of the inlet of the fan, more preferably, it is approximately 26% of the cross-sectional area of the inlet of the fan.

Preferably, the area of the inlet of the fan is within the range of 28 to 35% of the fan's circumferential outlet area, more preferably, it is approximately 32% of the fan's circumferential outlet area.

Preferably, the discharge area of the outlet of the fan is within the range of 19 to 27% of the fan's circumferential outlet area, more preferably, it is approximately 24% of the fan's circumferential outlet area.

Preferably, the length of the cyclone chamber is variable. This may be achieved by the cyclone chamber comprising a conduit and a sleeve concentric with and in slidable engagement with the conduit such that movement thereof varies the length of the cyclone chamber.

Preferably, the apparatus further comprises a fan casing for supporting the impeller suction fan, the fan having a plurality of radially extending vanes. The clearance between the outermost edge of the vanes and the fan casing may vary around the circumference of the fan such that, in operation, at least two thirds of the vanes are fully pressurised. Further, the forward edge of each vane of the fan may be 1/24th of the diameter of the fan greater than the radius of the cyclone chamber. The fan casing may be lined with a layer of high abrasion resistant material and the layer of high abrasion resistant material may further comprise a groove extending circumferentially around the fan casing. Each vane may be coated with a high abrasion resistant plastics material.

Preferably, the apparatus further comprises a separator for separating the granulated material from the cyclonic air stream.

Preferably, the feed assembly comprises a hopper extending partly into the cyclone chamber so that the material is fed into the path of the cyclonic air stream, or alternatively, it comprises a hopper and an auger-driven conveyor, the conveyer extending partly into the cyclone chamber or hopper so that the material is fed into the path of the cyclonic air stream. The distance between the feed assembly and the fan inlet may be adjustable.

Preferably, an externally generated frequency is induced into the cyclonic air stream.

Preferably, the material is processed within the cyclonic air stream before the air stream is disturbed by the fan.

The apparatus may include any one of or any combination of the following processes: processing, drying, and dewatering.

This phenomenon can be achieved by an impeller suction fan for a processor, according to a second aspect of the present invention comprising a central hub and plurality of vanes extending radially from the hub for creating a cyclonic air stream, wherein the cyclonic air stream includes non-conflicting effects of vacuum forming centripetal vortices, parts of which travel at supersonic speeds; series of harmonics and subsequent subharmonics inherent in the processor and induced; supersonic resonance; standing wave; thermal shock; pressure changes; cavitation; the stresses of which in combination convert the potential energy of material conveyed by the cyclonic air stream to kinetic energy.

Preferably, the vanes extend forwardly from the hub of the fan at an angle within the range of 30 to 50° to the axis of rotation of the fan, more preferably, the vanes of the fan extend forwardly at an angle of 45° to the axis of rotation of the fan.

Preferably, each of the vanes has a slot extending substantially parallel to the axis of rotation of the fan and having a width within the range 0.5 to 4% of the overall length of the vane. The slot may be located at a distance from the hub of the fan at the edge of the impeller inlet.

Preferably, the fan further comprises an interrupter located on the hub for disturbing the air within a zone immediately in front of the hub. The diameter of the interrupter may be approximately equal to the diameter of the hub.

Preferably, each vane extends radially at an angle within the range of 3 to 17° to the radius of the fan.

Preferably, each vane is concave in profile such that the concavity faces in the direction of rotation of the fan.

Preferably, each vane is coated with a high abrasion resistant plastics material.

Preferably, curvature of the vanes is adjusted for a particular material by computer aided design to take account of fluid dynamics and wear rates.

The apparatus for processing a material according to the first aspect of the present invention may incorporate an impeller suction fan according to the second aspect of the present invention.

This phenomenon can also be achieved by apparatus for processing a material, according to a third aspect of the present invention comprising a cyclone chamber; an impeller suction fan for creating a cyclonic air stream within the cyclone chamber, the fan having an inlet and an outlet for passage of the air stream therethrough; and a feed assembly for feeding material into the path of the cyclonic air stream for processing the material in the cyclone chamber, wherein the cross-sectional area of the cyclone chamber is within the range of 24 to 29% of the cross-sectional area of the inlet of the fan. Preferably, the cross-sectional area of the cyclone chamber is approximately 26% of the cross-sectional area of the inlet of the fan.

This can also be achieved by apparatus for processing a material, according to a fourth aspect of the present invention, comprising a cyclone chamber; an impeller suction fan for creating a cyclonic air stream within the cyclone chamber, the fan having an inlet and an outlet for passage of the air stream therethrough; and a feed assembly for feeding material into the path of the cyclonic air stream for processing the material within the cyclone chamber, wherein the area of the inlet of the fan is within the range of 28 to 35% of the fan's circumferential outlet area. Preferably, the area of the inlet of the fan is approximately 32% of the fan's circumferential outlet area.

This can also be achieved by apparatus for processing a material, according to a fifth aspect of the present invention, comprising a cyclone chamber; an impeller suction fan for creating a cyclonic air stream within the cyclone chamber, the fan having an inlet and an outlet for passage of the air stream therethrough; and a feed assembly for feeding material into the path of the cyclonic air stream for processing the material in the cyclone chamber, wherein the discharge area of the outlet of the fan is within the range of 19 to 27% of the fan's circumferential outlet area. Preferably, the discharge area of the outlet of the fan is approximately 24% of the fan's circumferential outlet area.

This can also be achieved by apparatus for processing a material, according to a sixth aspect of the present invention, comprising a cyclone chamber; a fan casing for supporting an impeller suction fan, the fan casing having an inlet and an outlet; an impeller suction fan having a plurality of radially extending vanes for creating a cyclonic air stream within the cyclone chamber via the inlet of the fan casing; and a feed assembly for feeding material into the path of the cyclonic air stream for processing the material within the cyclone chamber, wherein the clearance between the outermost edge of the vanes and the fan casing varies around the circumference of the fan such that, in operation, at least two-thirds of the vanes are fully pressurised.

This can also be achieved by apparatus for processing material, according to a seventh aspect of the present invention, comprising a cyclone chamber; an impeller suction fan for creating a cyclonic air stream within the cyclone chamber; and a feed assembly for feeding material into the path of the cyclonic air stream for processing the material within the cyclone chamber, wherein the length of the cyclone chamber is variable. In this way the length of the cyclone chamber can be adjusted to tune the apparatus to achieve the standing wave at the particular harmonic frequencies generated by a specially designed fan.

This can also be achieved by apparatus for processing a material, according to a eighth aspect of the present invention, comprising a cyclone chamber; a fan casing for supporting an impeller suction fan, the casing having an inlet and an outlet; an impeller suction fan having a plurality of radially extending vanes for creating a cyclonic air stream within the cyclone chamber via the inlet of the fan casing; and a feed assembly for feeding material into the path of the cyclonic air stream for processing the material within the cyclone chamber, wherein the forward edge of each vane of the fan is $1/24^{th}$ of the diameter of the fan greater than the radius of the cyclone chamber.

This can also be achieved by providing an impeller suction fan, according to a ninth aspect of the present invention, comprising a central hub and plurality of vanes extending radially from the hub for creating a cyclonic air stream, the vanes extending forwardly from the hub of the fan at an angle within the range of 30 to 50° to the axis of rotation of the fan. Preferably, the vanes extend at an angle of 45° to the axis of rotation.

This can also be achieved by providing an impeller suction fan, according to an tenth aspect of the present invention, comprising a central hub and a plurality of vanes extending radially from the hub for creating a cyclone air stream, each of the vanes having a slot extending substantially parallel to the axis of rotation of the fan and having a width within the range 0.5 to 4% of the overall length of the vane.

This can also be achieved by providing an impeller suction fan, according to a eleventh aspect of the present invention, comprising a central hub; a plurality of vanes extending radially from the hub for creating a cyclonic air stream, and an interrupter located on the hub for disturbing the air within a zone immediately in front of the hub.

In providing apparatus with an impeller suction fan in accordance with any one of the criteria mentioned above or any combination of these, the vortices created inside the chamber are such that the power is optimised. This is due to the harmonic frequencies which create high energy pockets which can cause the break up of very hard material Consequently rocks are powdered and material dried at a distance from the impeller within the cyclone chamber. Therefore, the turbulence created in the zone immediately in front of the impeller only play a very minor part in breaking up and drying the material. The design of the impeller, in relation to the fan inlet area; the diameter of the inlet tube and the length of the feed-in tube; combined with: the right number of blades on the impeller, rotating at a specific speed etc., can dramatically improve results and reduce abrasion.

The apparatus and fan produce an harmonic/frequency which sets up pulses from the standing configuration within the system, and this is critical because, on occasion pockets of air through the standing wave achieve a velocity beyond the sonic range. These conditions when optimised by the various aspects of the present invention, i.e. high local vorticity and high energy dissipation, will in some cases produce Abrikosov vortices When hard rock is processed by the machine, which has only one moving part, the ions orbiting the Abrikosov vortices will collide and may produce fusion.

Material is comminuted and/or dried before reaching the impeller, by a combination of thermal shock, cavitation, sudden extremes of pressure and frequency/harmonic interference which is sometimes beyond the sonic range.

The apparatus of the present invention is capable of grinding a material down by 1500:1 which is comparable with prior art devices which only achieve a reduction of 4:1.

The processing of the material may be further optimised by introducing an externally generated frequency into the cyclonic air stream.

An embodiment of the present invention will be described by way of example with reference to the accompanying drawings, in which:

Figure 1 is a side elevation of part of the apparatus according to the present invention showing the fan in part section;

Figure 2 is a part sectional side elevation of an alternative feed assembly of the apparatus according to the present invention;

Figure 3 is a transverse cross-section of the apparatus of Figure 1 taken along the line 3-3;

Figure 4 is a plan view of a vane of the fan of the present invention;

Figure 5 is a cross-section of the vane of Figure 4 taken along the line 5-5;

Figure 6 is a cross-section of the vane of Figure 4 taken along the line 6-6;

Figure 7 is a cross-section of the vane of Figure 4 taken along the line 7-7;

Figure 8 is a detailed plan view of a vane of the fan according the present invention,

Figure 9 is the profile of the vane of Figure 8;

Figure 10a is a side elevation of the interrupter according to the present invention;

Figure 10b is a plan view of the interrupter of Figure 10a; and

Figure 11 is a perspective view showing an embodiment of the apparatus according to the present invention.

In this description, general dimensions of the apparatus and its components are given together with the parameters which are by way of example only.

An embodiment of the apparatus according to the present invention is shown, in part, in Figure 1. The apparatus comprises a conical impeller suction fan 71 and a cyclone chamber 70. The cyclone chamber 70 is generally cylindrical and is arranged such that its longitudinal axis lies along the axis of rotation of the impeller suction fan 71.

The impeller suction fan 71 has an impeller 10 which typically has a diameter within the range 300 mm to 1220 mm. Smaller impellers can also be utilised in the apparatus of the present invention for certain laboratory, domestic, cosmetic or pharmaceutical applications. For an impeller of 610 mm diameter, the width of the impeller would be 196 mm. The impeller 10 is rotatably supported within a fan casing 19. To accommodate the impeller of diameter of 610 mm, the internal width of the fan casing would be approximately 203 mm. The casing 19 has an opening 63 in one of the side walls 61 thereof. The impeller 10 has an inlet 14 which is an annular ring and partly extends out of the casing 19 via the opening 63.

As can be seen from Figure 3, the casing 19 is generally spiral in shape having an outlet 72. The inner surface of the casing 19 may be lined with a wear plate (not shown) formed of a high abrasion resistant plastics material. The wear plate extends around approximately two-thirds of the circumferential area of the inner surface of the casing 19 from the point of minimum clearance 8-8. The wear plate helps to minimise wear of the casing wall. To further improve the performance of the wear plate, a groove may be formed in the wear plate which extends circumferentially around the casing to define a space which conforms to the air flows experienced within the casing 19.

The clearance between the inner surface of the casing 19 and the outer edge 76 of the impeller 10 increases in the direction of rotation of the impeller 10. The point of minimum clearance 8-8 occurs at an angle θ from the horizontal plane 9-9 which passes through the centre of rotation. The differences between the clearances of the impeller of the present invention and the impeller described with reference to US Patent No. 3147911 is depicted in Table 1 below:

θ	New Clearance (mm)	Old Clearance (mm)
33°	12.6	19.0
90°	43.2	76.2
135°	65.8	95.3
180°	71.1	109.2
235°	80.0	121.9
270°	114.3	152.4

TABLE 1

As can be clearly seen from the figures of Table 1, the clearances between the outer edge of the impeller of the present invention are reduced by approximately 30% so that at least two-thirds of radial vanes provided on the impeller 10 of the present invention are fully pressurised. Of the remaining vanes, at least 90° of travel, the first of the vanes has begun to depressurise and the remaining vanes are fully depressurised with the final vane just entering the zone of minimum clearance.

The discharge area is designed to be within the range of 19 to 27%, preferably 24%, of the fan's circumferential outlet area, and the area of the inlet of the fan is within the range 28 to 35%, preferably 32%, of the fan's circumferential outlet area. In the particular example specified, the discharge area is 457.2 mm multiplied by the width of the fan's discharge conduit 72.

The impeller 10 is keyed to one end of a shaft 16 which is supported by a bearing 17 mounted on the rear of the casing 19. A drive pulley 18 is fastened to the other end of the shaft 16. In operation, the pulley 18 is driven by a variable speed motor or internal combustion engine by means of at least one belt as shown in Figure 11. The impeller is driven at typical speeds of 4,500 to 7,000 rpm.

The cyclone chamber 70 comprises a cylindrical conduit 20 which, for the particular impeller mentioned above, has an inner diameter of 203.2 mm and a length of approximately 1.83m, such that the cross-sectional area of the conduit 20 is within

the range of 24 to 29%, preferably 26% of the cross-sectional area of the inlet 14 of the impeller 10.

One end of the conduit 20 is open to the atmosphere and is fitted with a cylindrical sleeve 24 in slidable engagement therewith. A slot 26 and locking clamp 25 enables the position of the sleeve 24 to be adjusted and locked into position, thereby varying the length of the conduit 20 to finely tune the harmonic frequencies of the air stream within the conduit during operation. The other end of the conduit 20 terminates in a frusto-conical section 21 which has an opening 62.

For an 380 mm diameter impeller having eight vanes operating at 5760 rpm, the optimum length of the conduit 20 is between 786 mm (i.e. the circumference of the inlet area of the impeller) and 931 mm. For a 610 mm diameter impeller, at 5760 rpm, the optimum length is 1298 mm (i.e. again the circumference of inlet area) up to 1851 mm.

Both optimum ranges given above are for when the machine runs at 5760 rpm. However, in the case of 380 mm diameter impeller, the inlet tube length range would apply to an impeller speed range of between 5760 rpm to 6827 rpm. The length of the conduit should not be less than 718 mm or more than 1150 mm, and for the impeller of diameter 610 mm, not less than 1126 or more than 1851 mm.

The cyclone chamber 70 is secured, for example by welding, to one side of a common supporting bracket 22, the side wall 61 of the casing 19 being removably fitted to the other side so that the opening 63 of the casing 19 and the mouth 62 of the expander section 21 are coincident. Thus the inlet 14 of the impeller 10 extends partly into the expander section 21 of the cyclone chamber 70.

A hopper 23 for receiving the material to be granulated is mounted on the conduit 20 adjacent the open end thereof and partly extending into the conduit. The hopper may be slidably mounted (not shown) on the conduit 20 so that its distance from the impeller may be adjusted. Such an arrangement allows the material to be introduced into the conduit 20 at a position which ensures the most efficient granulation.

Figure 2 shows an alternative feed assembly 44 which comprises a hopper 40, an auger-driven conveyor formed by a conduit 43 in which a screw 41 is driven to rotate by a geared motor 42. The conduit 43 of the feed assembly 44 extends partly into

the conduit 20 of the cyclone chamber 70 so that the material fed into the hopper 40 is conveyed by rotation of the screw 42 into the path of the cyclonic air stream during operation. Suitable supporting brackets (not shown) are provided for the feed assembly 44.

In circumstances where both gravity and auger-driven conveyor feed assemblies are provided, it is preferred that the auger-driven conveyor is mounted on the lower end 23a of the gravity hopper 23, discharge thereinto and from thence into the conduit 20 of the cyclone chamber 70. An advantage of such an arrangement is that both feed assemblies may utilise the means for adjusting the distance of the feed assembly from the impeller. Furthermore, the feed assembly may comprise an enlarged air inlet to increase the sir flow within the conduit.

Other types of feed assembly may also be utilised in the apparatus of the present apparatus, for example a pneumatic conveyor.

Details of the impeller 10 of the present invention will now be described with reference to Figures 3 to 10.

The impeller 10 comprises a plurality of radially extending vanes 11. Preferably, the number of vanes 11 number between 4 to 12 depending on the type of material to be granulated. The vanes 11 may be formed of and further may be coated with a layer of high abrasion resistant material to protect the vanes 11 against metal contamination as well as to provide a cushion to protect brittle particles such as diamonds which are released from ore such as kimberlite to allow large diamonds which would otherwise be crushed to emerge intact.

Each of the vanes 11 are offset from the radius of the impeller by an angle within the range of 3 to 17°. The vanes 11 are equispaced about a hub 15. The innermost edge 28 of each vane 11 is fitted into a corresponding axially aligned slot 29 in the hub 15. The hub 15 is provided with a central bore 37 and keyway 30 for receiving and being secured to the shaft 16. The spine 27 of each vane 11 is flat along both its chord and span, defining an isosceles triangle depicted by lines 80 and 81 and the innermost edge 28. The apex of the triangle coincides with the centre of the outermost edge of the vane 11.

As can be seen from figures 5, 6, 7 and 9, the profile of the vane 11 on either side of the spine 27 is generally arcuate in cross-section. The vane further comprises vane extensions 31 which may be flat and are angled at approximately 20° relative to the surface of the spine 27, but is preferably curved with rounded leading edges as shown by the broken line 31a. This curve induces laminar air flows over the surfaces thereby reducing drag and improving the efficiency of the fan. Each vane 11 is generally concave, the concavity of each vane 11 facing the direction of rotation of the impeller 10. Preferably, the curvature at the outermost edge of the vane is 1 to 3 mm.

The vane extension 31 extends into the inlet 14 of the impeller 10 at which point a slot 100 is formed in the vane 11, see Figure 9. The slot extends in a direction substantially parallel to the axis of rotation of the impeller 10. The width of the slot is preferably 0.5 to 4% of the overall length l of the vane 11. Typically on a vane of length 154 5 mm, the width of the slot is 2 mm. The vane extension 31 extends forwardly from the hub 15 of the impeller 10 by an angle α to the axis of rotation of the impeller 10. The angle α is within the range of 38 to 50°, for the particular vane of length 154.5 mm, the angle is 45°. The extension 31 extends in a forward direction at angle α to a point A to form a straight front edge 101. The point A is designed such that it extends at distance beyond the wall of the conduit 20 of the cyclone 70 by a distance of $1/24^{th}$ of the overall diameter of the impeller 10.

The front edge 73 which extends beyond the extension 31 is secured to an annulus 13, the inner peripheral margin of which provides an annular ring 14 which forms the inlet of the impeller 10. The internal diameter of the inlet 14 is approximately 406 mm. The rear edge 74 of each vane is secured to a plate 75 which comprises an outer annular ring 34 and a frusto-conical central portion 35 which, at its inner end, is secured to the hub 15 to provide a rigid structure.

An interrupter 90 may be fitted into the central bore 37 at the front side of the hub 15 facing the inlet 14 of the impeller 10. The interrupter is shown in Figures 10a and 10b. It comprises a disc 91 mounted on a central spine 92. The spine 92 is screw-threaded so that the interrupter 90 can be screw-fitted into the central bore 37 of the hub 15. The interrupter 90 further comprises a diametrical ridge 93 which is raised at one end. A hole 94 is bored through the raised portion of the ridge 93 at an angle of 45°.

The interrupter 90 disturbs the stationary air directly in front of the hub 15. The interrupter has a diameter approximately equal to the diameter of the hub 15.

The orientation and design of the impeller vanes can be further optimised by computer-aided design and can be further adjusted dynamically to compensate for any wear of the vanes. In particular, the degree of curvature of the vanes can be adjusted by computational fluid dynamics analysing wear patterns created by a given product and redesigning the vane to give optimum freedom from abrasion.

The granulation and drying of a material may be further improved by introducing an externally generated frequency to the cyclonic air stream by means of a speaker or electrical feed, for example. Typical frequencies may be 25 to 28 Hz, 57.6 Hz, 576 Hz for a fan running at 5760 rpm. Disassociation of water can be enhanced by introduction of a frequency of approximately 42.7 Hz.

A practical example of the apparatus according to the present invention is shown in Figure 11 It comprises a supportive framework 50 upon which is mounted the support bracket 22 to which the suction fan 71 and the cyclone chamber 70 are secured. A variable speed motor 57 with a drive pulley 58 is also mounted on the framework 50 and a belt 59 connects the drive pulley 58 to the pulley 18 of the fan 71. The means for varying the speed of the motor 57 are not shown. A belt guard 60 provides protection from the moving parts.

A conduit 51 connects the discharge conduit of the fan casing 19 to a cyclone separator 52 and receiving hopper 55 which are also mounted on the supportive framework 50 The lower end 54 of the separator 52 discharges the granulated material into the receiving hopper 55 from which it can be taken as required via a chute 56 by opening a shutter 77. The separated, clean air is then discharged from an exhaust conduit 53 into the atmosphere either directly or via filters for removal of any fine dust.

In operation, the motor 57 is run-up to speed and the length of the conduit 20 of the cyclone chamber 70 is adjusted by loosening the clamp 25 and moving the sleeve 24 axially until the optimum conditions are achieved for granulating a particular material by tuning the apparatus to the natural resonance frequency of the material. The sleeve 24 is then locked in situ by the clamp 25.

The types of materials which may granulated by the apparatus of the present invention ranges from coal, lignite, petroleum coke, mezotrace, oil shale, glass, drywall, ash, manure, sewage sludge, salt crystal, mineral and ore bearing sand, black sand, grains such as soybeans, corn, oats, barley, milo and rice.

The apparatus of the present invention can be utilised to dry wet clay, paper pulp, fish and bones into a fine powder. It is also useful for drying pigmentation cake which contains upto 50% water. The drying process is accomplished at a reduced length of time which using conventional methods has typically required at least 16 hours. It is assumed that the 4°C temperature and the free N_2 generated in the air flow suppresses combustion which normally occurs when pigmentation feedstock is powdered. Sewage cake utilised for fuel in combustion type gassifiers can be dried and deodorised by the apparatus of the present invention. Sewage slurry can be dewatered without pre-treatment, ideal for either fuel feedstock for plasma gassification and conversion into surplus town gas or chemical treatment processes for metal recovery and binding heavy metals against acid rain leachate as well as destroying all known pathogens in the process making it suitable for land reclamation. It can be utilised to process fish to fishmeal on ship providing a 20% saving.

The apparatus can also be utilised to dry ceramics and mineral compounds. Comminution of these can be avoided by slowing down the speed of the fan and feeding the material close to or in the expansion section in front of the fan inlet. Mining slurries can be dried either in powder form or dewatered sufficiently for chemical treatment for extraction of metals.

The material to be granulated is fed into the hopper 23 and is introduced into the path of the cyclonic air stream created by the suction fan 71 within the conduit 20 of the cyclone chamber 70. The material is completely fragmented within the conduit 20 before entering the fan due to the tuned harmonics carried by the vortices within the cyclonic air stream and is drawn by the cyclonic air stream into the inlet 14 of the impeller 10. The size of the exhaust ducting can be varied to adjust the air flow through the system.

A safety cut-off mechanism may be installed. During normal operation, there is virtually no load, particularly if a DC constant torque motor is utilised to drive the fan.

Therefore sensors can be provided to detect any increase in load, for example due to a large particle hitting the fan, to activate a cut-off switch and brake.

The sensors may alternatively, detect particularly large particles in transit such as diamonds and perform the same function. Sensors may also be utilised to detect large particles in the exhaust ducting and increase the speed of the fan to ensure that the material is finely granulated. Alternatively, the feed rates or the cyclone separator can be adjusted upon detection of large particles.

The forces within the vortices of the cyclonic air stream may release hydrogen and oxygen gases from certain materials, for example sewage sludge, to at least partly dry the material. In some circumstances it may be preferable to dry materials by heating the material, for example by subjecting the material to microwaves, either as is fed into the conduit 20 of the cyclone chamber 70, within the conduit 20 itself or feed into the fan casing. Introduction of microwaves also promotes separation between metals and their ores. Further, disassociation of the water due to the result of shearing of the water at 4°C (its densest point) results in the formation of singlet oxygen such as 0_3 and 0_4 (ozone) which destroys odours in bacteria contaminated products such as sewage cake. Further, H_2 formed by the disassociation of water may recombine with some of the oxygen to form water which may be exhausted out via the fan or it may form around the inner surface of the conduit 20 and stream out of the open end of the conduit counter to the air stream within the conduit.

Typically, in the apparatus of the present invention, an impeller of 380 mm diameter having eight vanes running at a speed of 5760 rpm will dry 2.16 tons per hour of sewage (comprising 70% water, 30% solids), which has been diced into 4.5 cm^3 cubes. Further such an arrangement can granulate rock of 15 cm^3 at a rate of 5 tons per hour. Typically, a 610 mm diameter impeller having eight vanes will dry 3.6 tons of sewage per hour (comprising 70% water, 30% solids), diced into 7.5 cm^3 cubes or granulate rock of 25 cm^3 at a rate of 8 tons per hour.

In the case of an impeller having eight vanes running at 5760rpm, 3,145,728 pulses are generated by the blade and hub, according the present invention, within the vortices which greatly improves the drying and comminution process.

In the light of this disclosure, modifications of the described embodiment, as well as other embodiments, all within the scope of the appended claims will now become apparent to persons skilled in the art.

CLAIMS:

1. Apparatus for processing a material comprising a cyclone chamber; an impeller suction fan for creating a cyclonic air stream within the cyclone chamber, the fan having an inlet and an outlet for passage of the air stream therethrough; and a feed assembly for feeding material into the path of the cyclonic air stream for processing the material in the cyclone chamber, wherein the cyclonic air stream includes non-conflicting effects of vacuum forming centripetal vortices, parts of which travel at supersonic speeds; series of harmonics and subsequent subharmonics inherent in the apparatus and induced; supersonic resonance; standing wave; thermal shock; pressure changes; cavitation; the stresses of which in combination convert the potential energy of material conveyed by the cyclonic air stream to kinetic energy.

2. Apparatus according to claim 1, wherein the cross-sectional area of the cyclone chamber is within the range of 24 to 29% of the cross-sectional area of the inlet of the fan

3. Apparatus according to claim 1 or 2, wherein the cross-sectional area of the cyclone chamber is approximately 26% of the cross-sectional area of the inlet of the fan.

4. Apparatus according to any one of preceding claims, wherein the area of the inlet of the fan is within the range of 28 to 35% of the fan's circumferential outlet area.

5. Apparatus according claim 4, wherein the area of the inlet of the fan is approximately 32% of the fan's circumferential outlet area.

6. Apparatus according to any one of the preceding claims, wherein the discharge area of the outlet of the fan is within the range of 19 to 27% of the fan's circumferential outlet area.

7. Apparatus according to claim 6, wherein the discharge area of the outlet of the fan is approximately 24% of the fan's circumferential outlet area.

8. Apparatus according to any one of the preceding claims, wherein the length of the cyclone chamber is variable.

9. Apparatus according to claim 8, wherein the cyclone chamber comprises a conduit and a sleeve concentric with and in slidable engagement with the conduit such that movement thereof varies the length of the cyclone chamber.

10. Apparatus according to any one of the preceding claims wherein, the apparatus further comprises a fan casing for supporting the impeller suction fan, the fan having a plurality of radially extending vanes

11. Apparatus according to claim 10, wherein the clearance between the outermost edge of the vanes and the fan casing varying around the circumference of the fan such that, in operation, at least two thirds of the vanes are fully pressurised.

12. Apparatus according to claim 10 or 11, wherein the forward edge of each vane of the fan being 1/24th of the diameter of the fan greater than the radius of the cyclone chamber.

13. Apparatus according to any one of claims 10 to 12, wherein the fan casing is lined with a layer of high abrasion resistant material.

14. Apparatus according to claim 13, wherein the layer of high abrasion resistant material comprises a groove extending circumferentially around the fan casing.

15. Apparatus according to claims 13 or 14, wherein each vane is coated with a high abrasion resistant plastics material.

16. Apparatus according to any one of the preceding claims, wherein the apparatus further comprises a separator for separating the granulated material from the cyclonic air stream.

17. Apparatus according to any one of the preceding claims, wherein the feed assembly comprises a hopper extending partly into the cyclone chamber so that the material is fed into the path of the cyclonic air stream.

18. Apparatus according to any one of claims 1 to 16, wherein the feed assembly comprises a hopper and an auger-driven conveyor, the conveyer extending partly into the cyclone chamber or hopper so that the material is fed into the path of the cyclonic air stream.

19. Apparatus according to any one of the preceding claims, wherein the distance between the feed assembly and the fan inlet is adjustable.

20. Apparatus according to any one of the preceding claims, wherein an externally generated frequency or microwave is induced into the cyclonic air stream.

21. Apparatus according to any one of the preceding claims, wherein the material is processed within a feeder tube of the cyclonic air stream prior to the turbulence in front of the fan.

22. Apparatus according to any one of the preceding claims, wherein the apparatus processes a material which includes any one of or any combination of the following processes: granulating, drying, and dewatering.

23. Apparatus for processing a material substantially as hereinbefore described with reference to any one of the accompanying drawings.

24. An impeller suction fan for a processor comprising a central hub and plurality of vanes extending radially from the hub for creating a cyclonic air stream, wherein the cyclonic air stream includes non-conflicting effects of vacuum forming centripetal vortices, parts of which travel at supersonic speeds; series of harmonics and subsequent subharmonics inherent in the processor and induced; supersonic resonance; standing wave; thermal shock; pressure changes; cavitation; the stresses of which in combination convert the potential energy of material conveyed by the cyclonic air stream to kinetic energy.

25. An impeller suction fan according to claim 24, wherein the vanes extend forwardly from the hub of the fan at an angle within the range of 30 to 50° to the axis of rotation of the fan.

26. An impeller suction fan according to claim 25, wherein the vanes of the fan extend forwardly at an angle of 45° to the axis of rotation of the fan.

27. An impeller suction fan according to any one of claims 24 to 26, wherein each of the vanes has a slot extending substantially parallel to the axis of rotation of the fan and having a width within the range 0.5 to 4% of the overall length of the vane.

28. An impeller suction fan according to claim 27, wherein the slot is located at a distance from the hub of the fan at the edge of the impeller inlet.

29. An impeller suction fan according to any one of claims 24 to 28, wherein the fan further comprises an interrupter located on the hub for disturbing the air within a zone immediately in front of the hub.

30. An impeller suction fan according to claim 29, wherein the diameter of the interrupter is approximately equal to the diameter of the hub.

31. An impeller suction fan according to any one of claims 24 to 30, wherein each vane extends radially at an angle within the range of 3 to 17° to the radius of the fan.

32. An impeller suction fan according to any one of claims 24 to 31, wherein each vane is concave in profile such that the concavity faces in the direction of rotation of the fan.

33. An impeller suction fan according to any one of claims 24 to 32, wherein each vane is coated with a high abrasion resistant plastics material.

34. An impeller suction fan according to any one of claims 22 to 33, wherein curvature of the vanes is adjustable by computational fluid dynamics analysing wear patterns created by a given product and redesigning the vane to give optimum freedom from abrasion.

35. An impeller suction fan substantially as hereinbefore described with reference to any one of the accompanying drawings.

36. Apparatus for processing a material according to any one of claims 1 to 23 in combination with an impeller suction fan according to any one of claims 24 to 35.

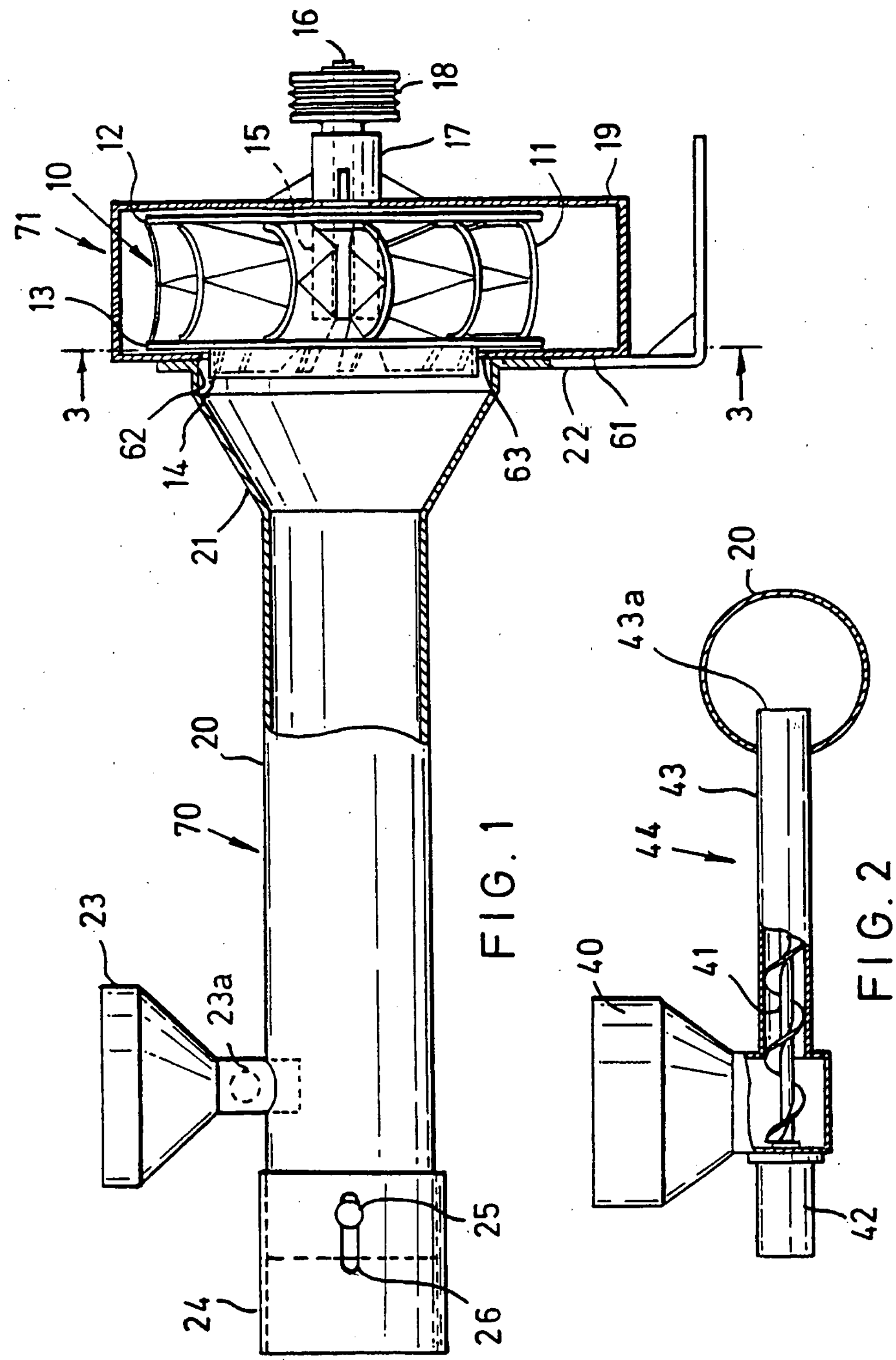

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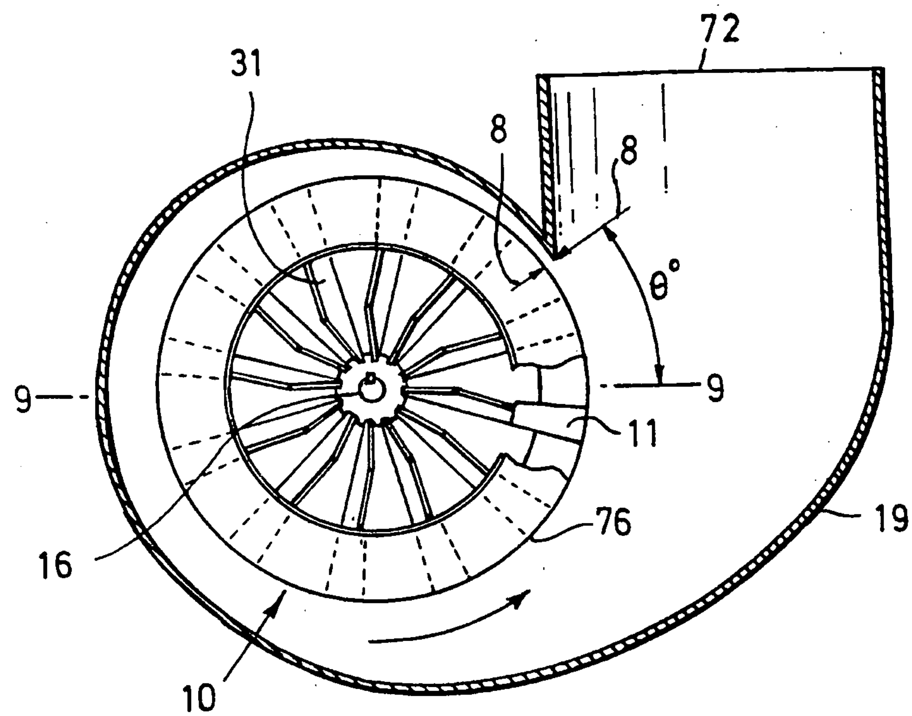
FIG. 1

FIG. 2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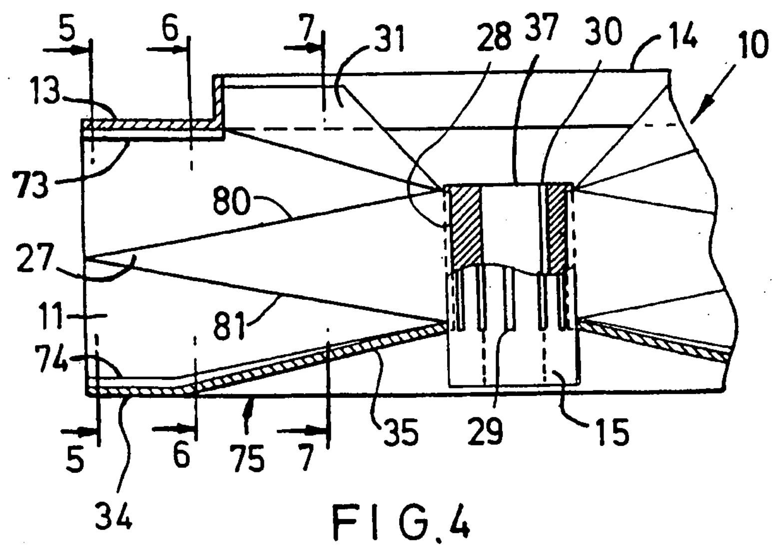
F I G. 3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F I G. 4

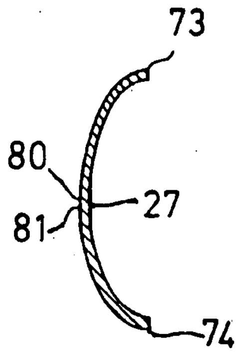

FIG. 5

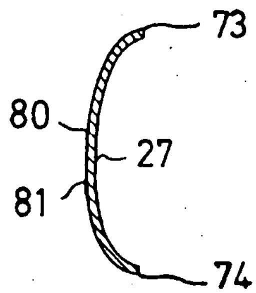

FIG. 6

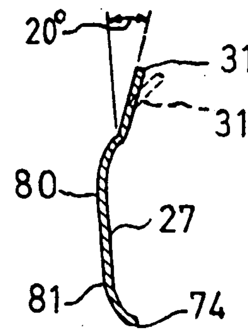

FIG. 7

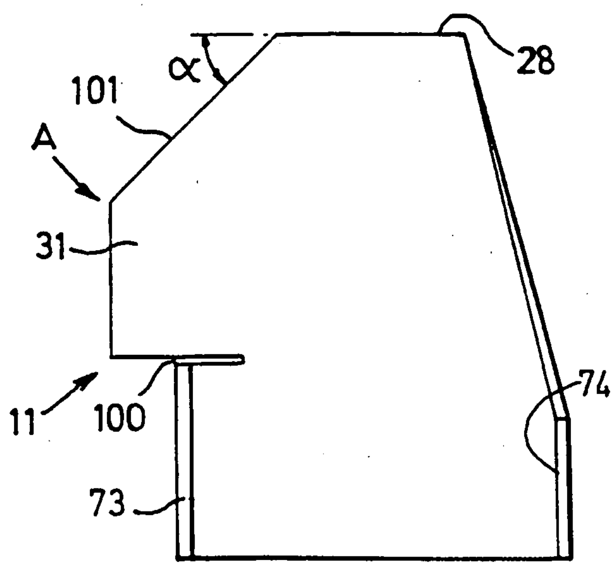

FIG. 8

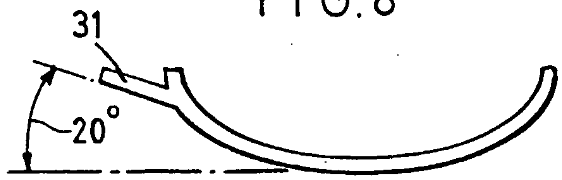

FIG. 9

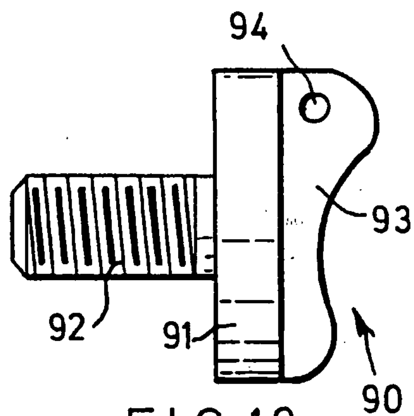

FIG. 10a

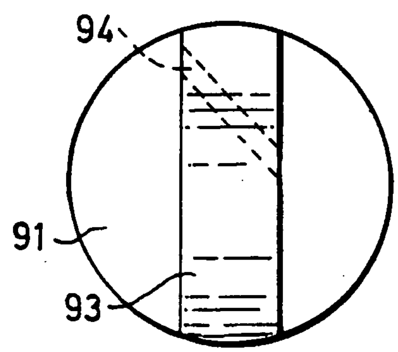

FIG. 10b

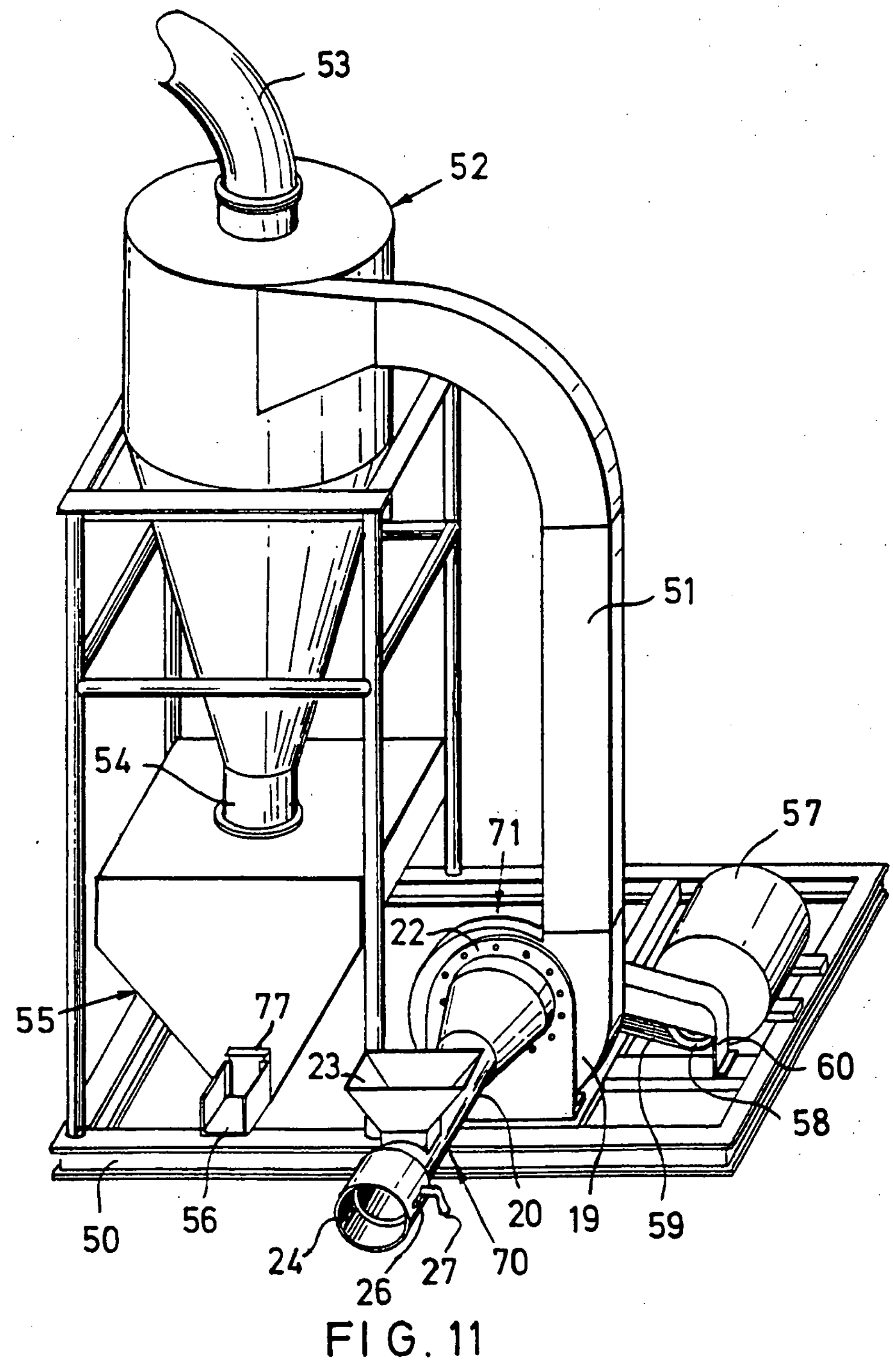

FIG. 11

INTERNATIONAL SEARCH REPORT

International application No.
PCT/GB 98/00422

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: B02C 19/18, F26B 5/00, C02F 11/12
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: B02C, F26B, C02F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 8604527 A1 (CP COAL MILLS, INC.), 14 August 1986 (14.08.86), page 17, line 22 - page 19, line 24, figures 1-7	1-7,10-18, 21-26,31-33, 35,36
	--	
X	US 4892261 A (THOMAS E. ROLLE ET AL), 9 January 1990 (09.01.90), column 3, line 14 - line 62; column 4, line 60 - column 5, line 26, figures 1-11	1,8-12, 17-19,21-28, 31,32,35,36
	--	
X	US 3255793 A (F.H. CLUTE), 14 June 1966 (14.06.66), column 4, line 54 - column 5, line 19, figures 1-8	1,10,21-26, 31,32
	--	

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" erlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 May 1998	10.06.98

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	ULF NYSTRöM

INTERNATIONAL SEARCH REPORT

International application No.
PCT/GB 98/00422

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4391411 A (WILLIAM A. COLBURN), 5 July 1983 (05.07.83), figure 1, claim 1 --	1
A	US 4390131 A (JACK D. PICKREL), 28 June 1983 (28.06.83), column 7, line 40 - column 10, line 51, figure 2 -- --------	1-3

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INTERNATIONAL SEARCH REPORT
Information on patent family members

29/04/98

International application No.
PCT/GB 98/00422

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		CA 1305116 A	14/07/92
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US 4892261 A	09/01/90	US 4852818 A	01/08/89
		US 4718609 A	12/01/88
US 3255793 A	14/06/66	NONE	
US 4391411 A	05/07/83	NONE	
US 4390131 A	28/06/83	NONE	